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"Black Pellets" – A Financial Analysis of Costs and Benefits

A revised and updated analysis

By William Strauss, October, 2014

FutureMetrics published the original paper on this topic in July, 2014. In the months following the original paper we have received a number of comments from technology developers and other as well as some new data. This paper is a revised version of the original. The most important change is that this new analysis quantifies the benefit of the avoided costs of building dry storage.

This paper is also accompanied by a new interactive dashboard that can be downloaded from the FutureMetrics website: www.FutureMetrics.com . The dashboard allows any user to change all of the important inputs to the model and view the outcome in a simple chart that shows the relative net benefit (or penalty) compared to white pellets of using torrefied or steam exploded pellets. The dashboard is highly comprehensive and provides critical insight into how that relative benefit or penalty varies with changes in any or all of the key inputs to the model.

As in the earlier paper, this white paper will deconstruct the components of the financial benefits and costs of black pellets. It will compare torrefied pellets and steam exploded pellets with traditional white pellets.

This analysis will use white pellets as the benchmark and will calculate the net benefit or penalty of producing torrefied or steam exploded pellets versus white pellets. The analysis will first calculate the value of a shipload of white, torrefied, and steam exploded pellets delivered to a foreign port. It will then calculate the additional costs required to manufacture torrefied and steam exploded pellets versus white pellets. **This updated paper also includes the estimated financial benefit of hydrophobicity and assumes that the utility buyer will be willing to pay extra for the fuel based on the avoided cost of building dry storage.** This updated paper also quantifies the avoided cost of port dry storage for the producer. Subtracting the additional costs from the additional value will provide the final metric which will determine if there is a valid economic argument for torrefaction and steam explosion.

Both torrefaction and steam explosion result in higher energy density and higher bulk density pellets. In both processes, a comparison of the incoming wood and final densified product shows that the loss of mass is greater than the loss of energy. That change in bulk and energy densities is advantageous to logistics. More tonnes per unit of volume and more energy per tonne lowers the delivery cost per unit of energy. This analysis will measure the energy in gigajoules (GJ) per metric tonne and all of the comparisons will be made based on the cost or benefit per GJ.

Higher Value for Higher Bulk and Energy Density

The analysis will assume that the buyer is willing to pay the same base price per GJ for any of the three types of pellets. The price for steam exploded pellets will be adjusted based on the estimated avoided cost per GJ for not having to build dry storage[1]. Using an assumed price of $160 per metric tonne FOB for white pellets and using the energy densities in the table below, the value of a GJ FOB is $9.14.

[1] There is no disagreement on the waterproof characteristics of steam exploded pellets. There is a spectrum of claims on the waterproof characteristics of torrefied pellets. Some technology developers claim waterproofness,

	Energy (GJ/tonne)
White	17.5
Torrefied	22.0
Steam Exploded	19.5

The assumed bulk densities of the three types of pellets are shown in the table below.

	Bulk Density (kg/m^3)
White	650
Torrefied	700
Steam Exploded	750

The assumed volume of the ship that is loaded with pellets is 60,000 cubic meters. For all three types of pellets the ship will "cube out" (fill up completely) before reaching a maximum weight limit. The table below shows the tonnes and GJ that would be loaded on a 60,000 m^3 ship.

	GJ/m^3	Vessel volume (m^3)	Tonnes on board	GJ on board
White	11.38	60,000	39,000	682,500
Torrefied	15.40	60,000	42,000	924,000
Steam Exploded	14.63	60,000	45,000	877,500

Assuming a shipping cost of $23/tonne[2] for a 45,000 tonne load of steam exploded pellets, the estimated costs per tonne for shipping pellets are shown below.

	shipping cost per tonne
White	$23.00
Torrefied	$21.36
Steam Exploded	$19.93

As the table above shows, fewer tonnes on a fully filled ship result in higher costs per tonne. This analysis also accounts for losses due to breakage (fines). The literature on fines produced from torrefied and steam exploded pellets is limited and in some cases contradictory. Based on information from

some claim water resistance, and some do not claim either. The default in this analysis is that torrefied pellets are not waterproof. The interactive dashboard allows that to be switched.

[2] Based on Argus Biomass Markets report, October 8, 2014, to ARA (Amsterdam, Rotterdam, Antwerp) from Savannah, GA for a 45,000 tonne shipment on a supramax vessel.

several presentations on this topic, this analysis assumes the following unrecoverable losses during loading, transport, and unloading before delivery to the land-based carrier at the foreign port.

	Fines
White	1.5%
Torrefied	1.0%
Steam Exploded	0.5%

This yields a final net value of the delivered fuel. The table below shows the total value of the delivered fuel for each of the three types of pellets based on a FOB value of $9.14/GJ minus shipping costs. The total shipping costs are identical for each since the assumption is that the ships are fully filled in all three scenarios. The costs per tonne are different because there are also fewer tonnes on the ships carrying lower bulk density pellets.

	Value of Delivered Pellets	Cost of Shipping	Net value of pellets at foreign port	Margin over white pellets
White	$6,146,400	$897,000	$5,249,400	$0
Torrefied	$8,363,520	$897,000	$7,466,520	$2,217,120
Steam Exploded	$7,982,743	$897,000	$7,085,743	$1,836,343

This yields the following net value of the pellets at the foreign port in $/GJ. The table also shows the relative value added over white pellets.

	Net value of pellets at foreign port in $/GJ	Margin over White per GJ at the Foreigh Port
White	$7.817	$0.000
Torrefied	$8.162	$0.345
Steam Ex.	$8.116	$0.299

As would be expected, the value of a delivered shipload of higher bulk and energy density fuel is higher than for white pellets.

Higher Cost to Produce

Producing torrefied and steam exploded pellets requires higher costs. The table below[3] shows the wood demands at an assumed moisture content of 50% for green wood and hog fuel and 5% for the finished pellets. (odt = "oven dry tonne" which would be the weight of the wood with 0% moisture content.)

The default for this section of the analysis is that the energetic gas released in the torrefaction process is sufficient to fuel both the reactor and the pre-dryer. This is based on data from two major technology developers. The default for steam explosion is that the wood enters into the process reactor green. Therefore for this analysis the assumption is that there is no extra wood needed for pre-drying the steam explosion process feedstock. These assumptions can be adjusted in the dashboard.

This analysis also assumes that none of the energetic content in the liquid by-product from the steam explosion process is recaptured. Therefore the energy needed to generate steam is derived from a waste wood (hog fuel) boiler. Both the tonnes of steam needed per tonne of pellets and the amount of wood needed to generate that steam can be adjusted in the dashboard.

Per tonne of pellets - feedstock and fuel at 50% and pellets at 5% moisture content	Torrefied	Steam Exploded	White
Extra Fuel for Pre-Drying	0%	0%	
Dryer fuel consumption (odt)	0.000	0.000	0.133
Steam consumption (tonnes of Steam per tonne of Pellets)	0.000	1.400	0.000
Additional Wood for steam production (odt)	0.000	0.211	0.000
Wood going into the reactor (odt)	1.350	1.110	0.000
Total wood to make a tonne of pellets (odt)	1.350	1.321	1.083
Green Wood at 50% moisture content/tonne of pellets	**2.700**	**2.642**	**2.165**

As the table shows, higher wood input is needed for both versions of "black" pellets.

The wood costs, and the bulk and energy densities yield the following wood cost per GJ. The lost energy from the liquid byproduct of steam explosion

[3] The values in the table are based on assumptions on wood energy content and process efficiency that may vary by location and process. The bottom line values will be different for different locations and technologies. The values are within a reasonable margin of error.

	Tonnes on board	Wood Cost	GJ on board	Wood Cost per GJ
White	39,000	$2,874,668	648,375	$4.212
Torrefied	42,000	$4,082,400	970,935	$4.418
Steam Ex.	45,000	$3,976,200	874,125	$4.531

The table below shows the additional wood costs over the costs for white pellets based on feedstock at $36/green tonne and dryer and steam generator hog fuel at $20/green tonne.

	Additional wood cost	Additional Wood Cost per Tonne
White	$0	$0
Torrefied	$1,207,732	$28.76
Steam Exploded	$1,101,532	$24.48

The total additional wood costs are computed for the same tonnage as the delivered ship load used above.

Also additional O&M costs are assumed for the torrefaction and steam explosion processes. In both cases this analysis assumes an additional black pellet cost for O&M, including electricity, of $4.00/tonne ($34/tonne for black pellets and $30/tonne for white pellets).

The increase in capital costs also have to be accounted for. The cost of the equipment only (not including other costs such as engineering, legal, land, etc.) per installed tonne per year of capacity for a white pellet plant averages about $160. FutureMetrics has very limited data on the extra capital cost for adding the reactors and other equipment needed for both black pellet processes. For this analysis the assumption is that cost per tonne of capacity per year for a torrefied project and for a steam exploded project is about $255 (versus $210 for a white pellet project). The total additional amortized CAPEX column is based on the shipload tonnages shown above. [These and all other assumed inputs can be adjusted in the dashboard.]

	Amortized capex per tonne
White	$23.06
Torrefied	$28.00
Steam Ex.	$28.00

Normalizing all of these costs to $/GJ yields the following.

	Wood Cost per GJ	O&M costs per GJ	Amortized Capex per GJ
White	$4.212	$1.714	$1.709
Torrefied	$4.418	$1.545	$1.650
Steam Ex.	$4.531	$1.744	$1.862

The Valuation of Hydrophobicity (waterproofness)

The waterproof pellets provide a quantifiable benefit (i.e., a negative cost) in the avoided cost of dry storage. There are two major dry storage costs: at the shipping port and at the power plant.

For the shipping port the model assumes storage for 35,000 tonnes with loading infrastructure at a capital cost of $10,000,000[4]. Amortizing that over 10 years at a 7% discount rate and assuming 250,000 tons per year of flow, the cost is about $5.60/tonne. This is subtracted from the O&M cost for the steam exploded pellets (the interactive dashboard allows these assumption to be changed for the torrefied pellets if they are to be considered waterproof). This changes the table above by lowering the O&M cost per GJ for the steam exploded pellets from an estimated $1.744/GJ to $1.452/GJ.

	O&M costs per GJ
White	$1.714
Torrefied	$1.545
Steam Ex.	$1.452

The forgone cost to the utility also has value. This analysis sets the base cost of building dry storage at $350 per kW of power plant capacity. The baseline is then adjusted for the co-firing rate (15% for this model but the dashboard allows a selection for up to 100%) and for the number of weeks of pellet fuel supply the power plant needs (3 weeks for this analysis but adjustable with the dashboard). The cost of building sufficient dry storage volume is then calculated and that is amortized over 10 years at a 7% discount rate. The values are further adjusted for power plant thermal efficiency and capacity factor (35% and 85% respectively for this analysis). The resulting metric is $0.65/GJ of avoided cost to the power plant from not having to build white pellet dry storage. This benefit netted out of the $/GJ costs.

Taking the delivered value of the pellets and subtracting the costs, and including the benefit of avoided dry storage for the waterproof pellets, the relative net benefit of the black pellets over the white pellets is shown in the table below.

[4] This is based very generally on several actual quotes.

	Net Benefit over White Accounting for Dry Storage/GJ
White	$0.000
Torrefied	$0.50
Steam Ex.	$0.81

Based on the assumptions used in this analysis, there is a net improvement in the value of a shipload of torrefied and steam exploded pellets over white pellets.

If the torrefied pellets are considered waterproof, the net benefit is as follows.

	Net Benefit over White Accounting for Dry Storage/GJ
White	$0.000
Torrefied	$1.41
Steam Ex.	$0.81

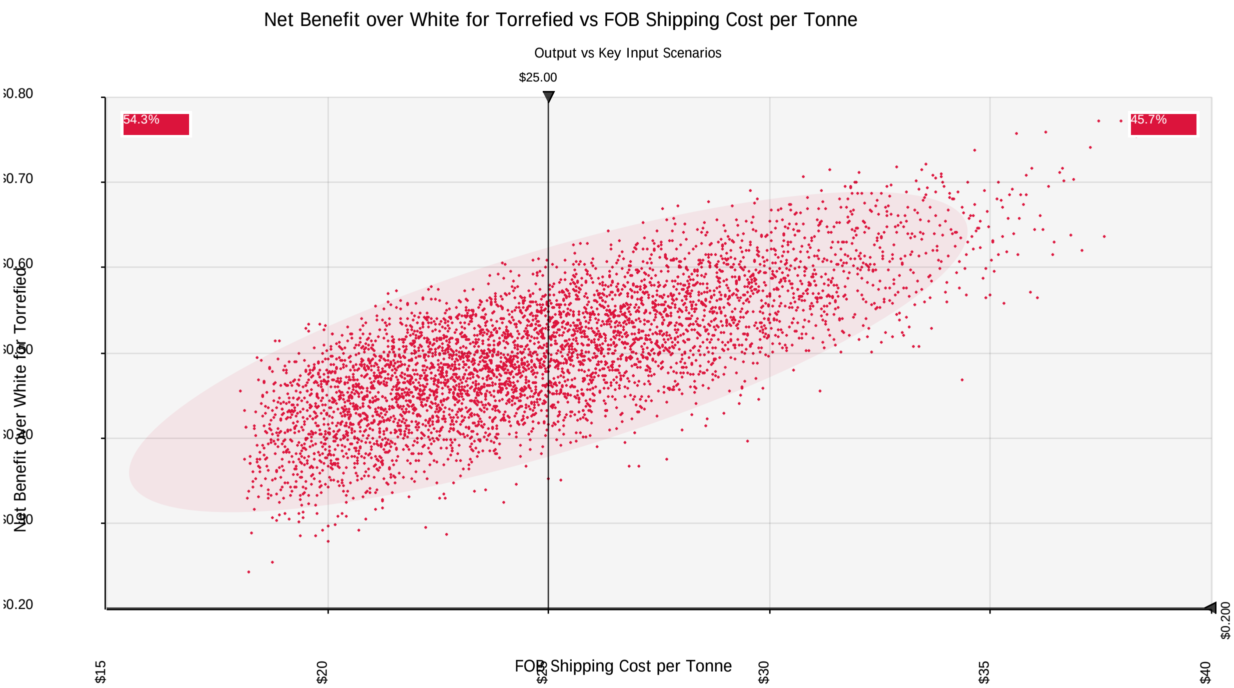
Sensitivity Analyses

There are several inputs to the model that have significant effects on the value of black pellets relative to white pellets. These impacts are tested by using simulation techniques[5].

Since one of the benefits of higher energy and bulk density pellets is to lower the cost per tonne for shipping, the impact of higher FOB rates should improve the benefit of black over white pellets. The two charts[6] below show this outcome.

[5] FutureMetrics uses Decision Tools' @RISK software by Palisade Corporation to build and run Monte Carlo simulations. Key inputs are assigned probability distributions that model the possible values they can take on in the near future. Each iteration of the simulation randomly selects values from those inputs based on the distributions. The outcomes from 5000 iterations illustrate the impacts of changes in inputs on the relative benefit (or penalty) of using black pellets versus white.

[6] The dots on the charts show the outcome of each of 5000 iterations of the simulation. The shaded ellipse defines the 95% confidence interval.



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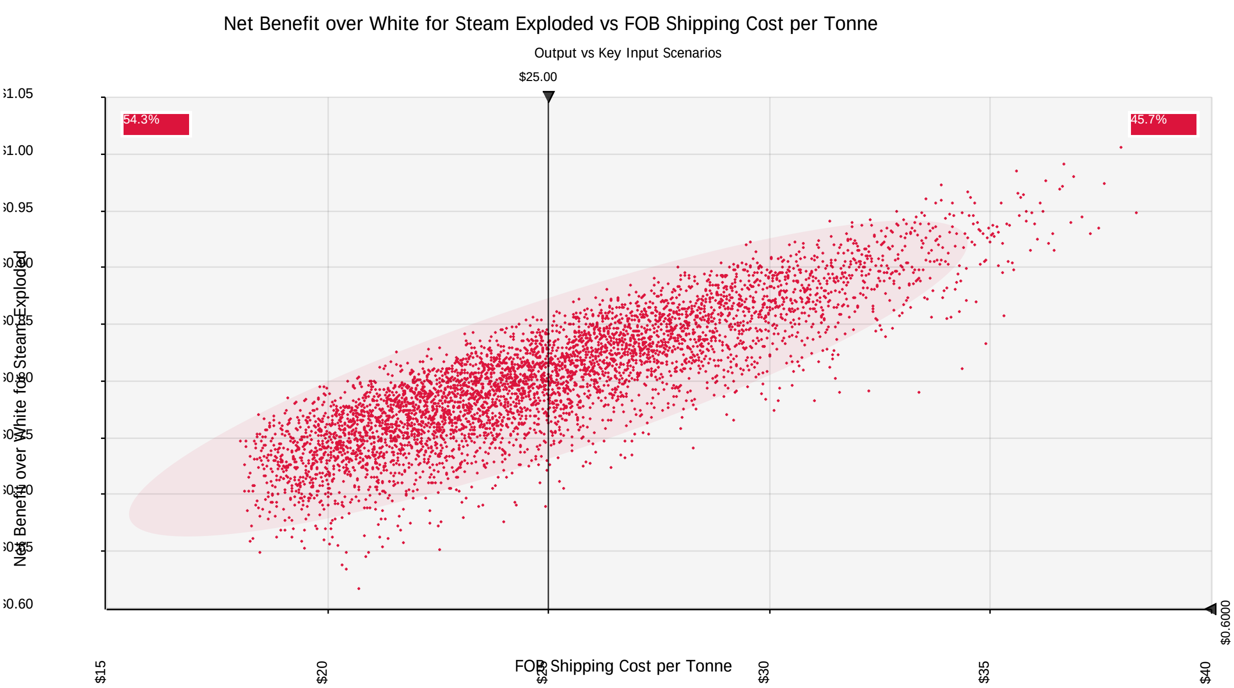
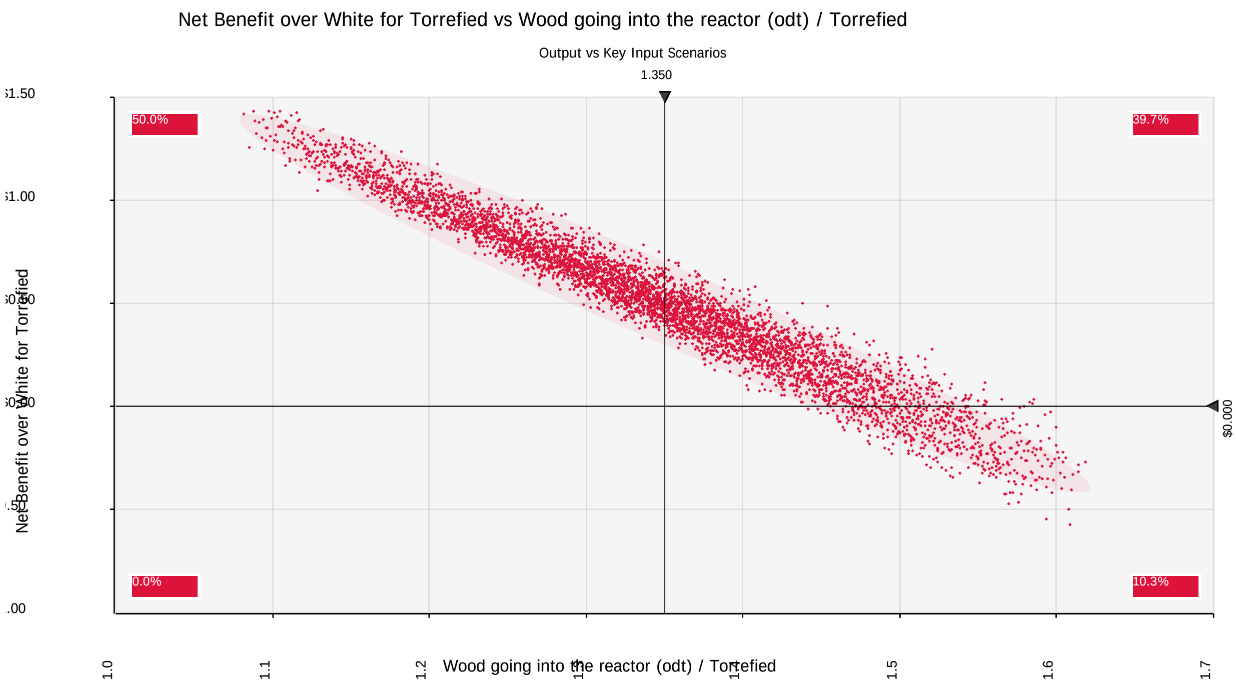
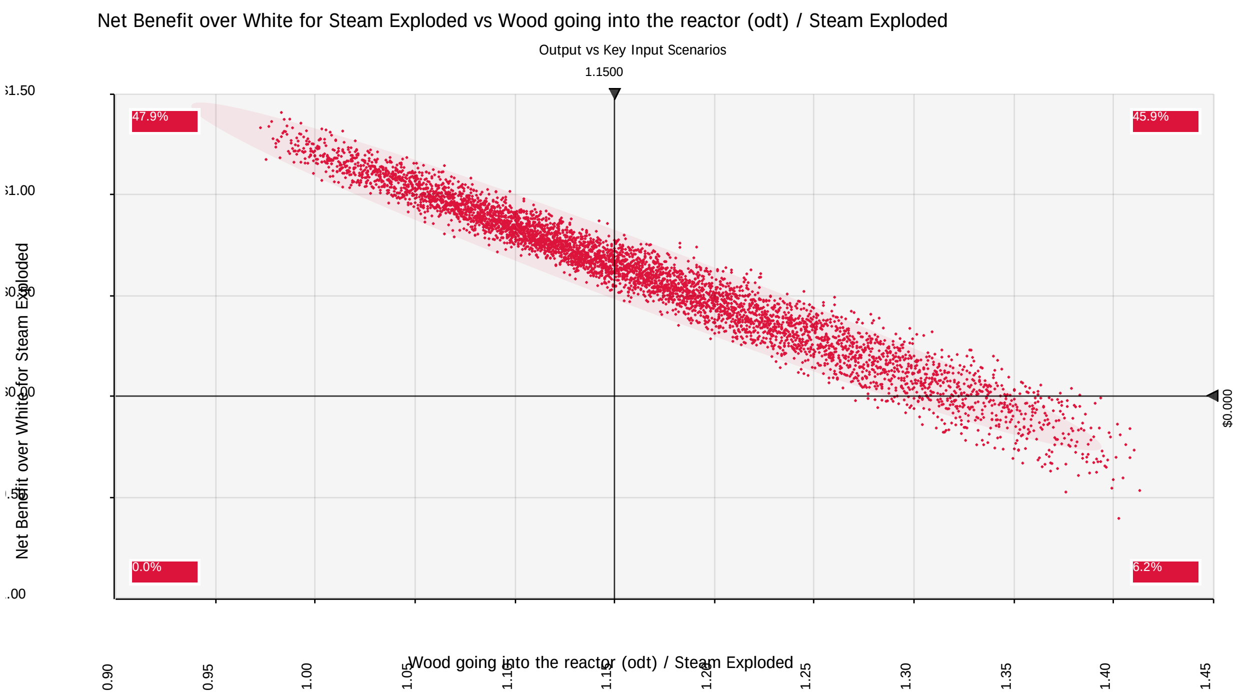
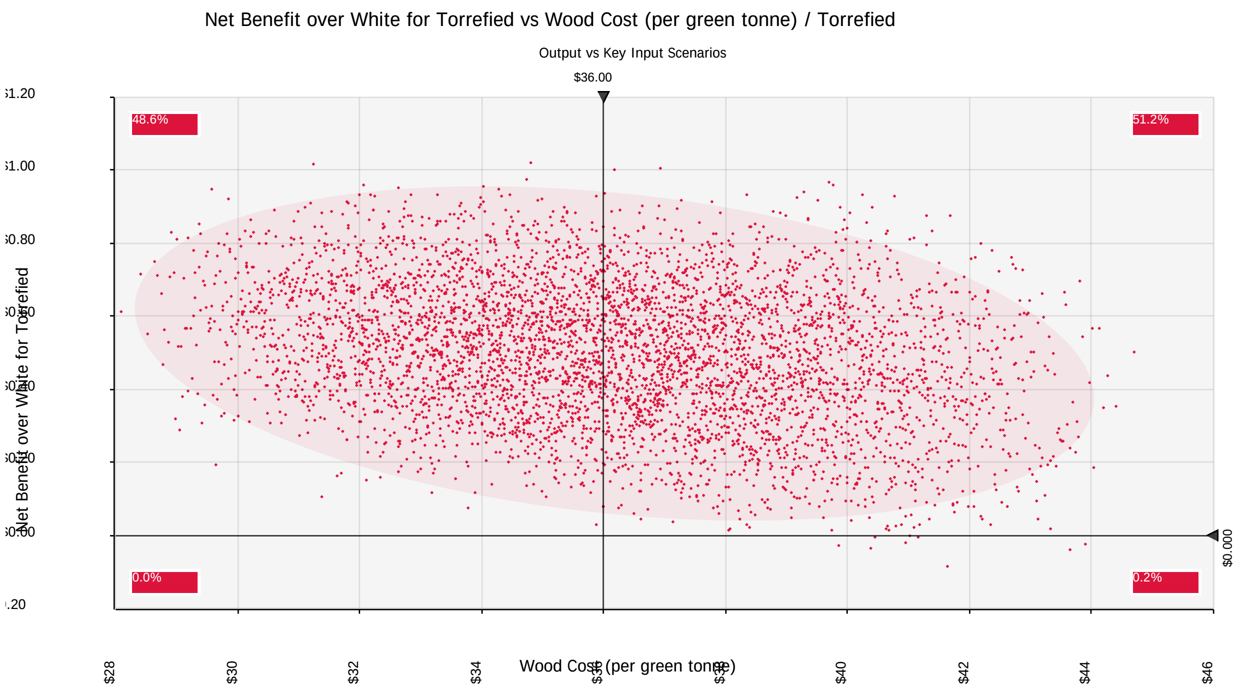


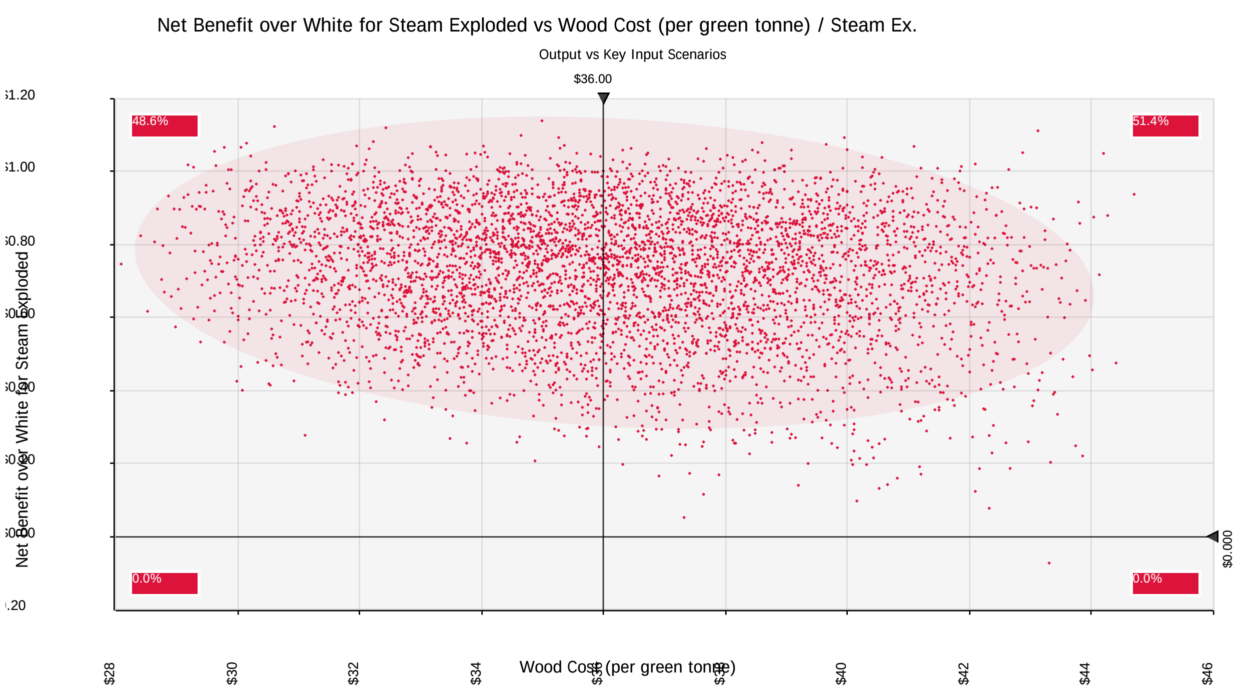
The amount of wood entering the reactors has a strong impact on the viability of the black pellet processes. The charts below illustrate how important it is for the processes to be efficient in their use of wood. Both torrefied and steam exploded pellets lose their advantage with inefficient technologies.





Wood cost per tonne impacts all three types of pellets. There is a small negative impact on the relative benefit as wood costs increase.





Conclusion

The advantage of black pellets versus white pellets is based on the improved transportation costs per unit of energy delivered and, if waterproof, the value of the avoided costs for dry storage of both the shipping port and at the utility. The buyer could pay a lower price per GJ and the seller can earn a better profit per GJ as long as those adjustments do not take the benefit below zero.

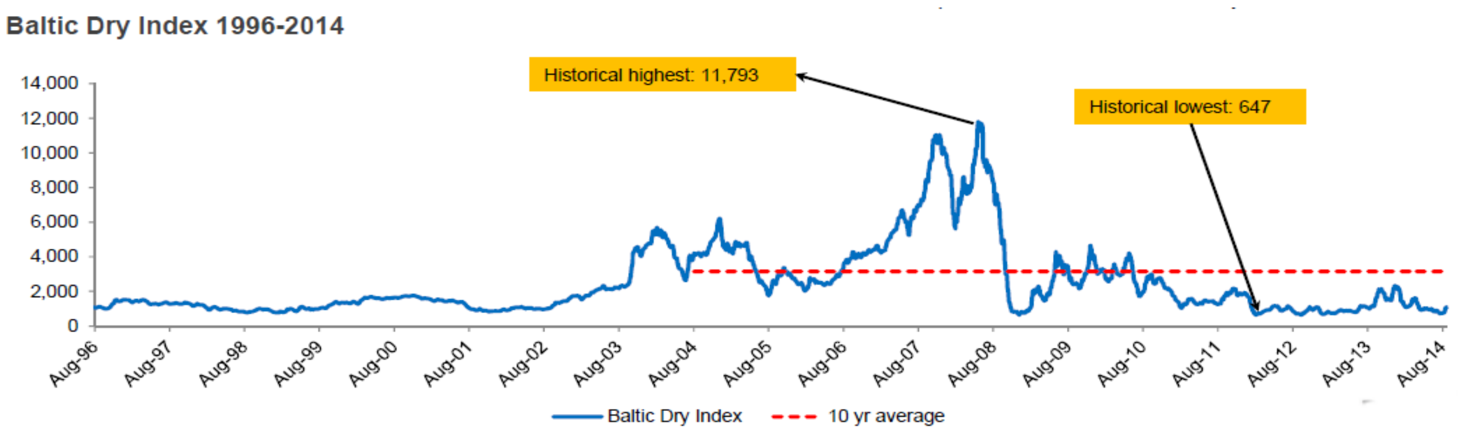
The value of waterproofness is essential to the net benefit for steam exploded pellets. The tables below shows the net benefits if we assume all black pellets are not waterproof or are waterproof.

	Net Benefit over White Accounting for Dry Storage/GJ	Waterproof?
White	$0.000	
Torrefied	$0.50	No
Steam Ex.	-$0.14	No

	Net Benefit over White Accounting for Dry Storage/GJ	Waterproof?
White	$0.000	
Torrefied	$1.41	Yes
Steam Ex.	$0.81	Yes

This analysis does not quantify improved grindablity. Improved grinding characteristics can lower operating costs for the power plant. However, based on data we have reviewed, this impact on the net benefit is relatively small compared to the logistics benefits to transport and storage.

As shipping costs rise, the attractiveness of black pellets relative to white pellets increases. Shipping costs are currently near historical lows and are likely to rise. The advantage increases for higher shipping costs regardless of the reason (for example, longer distances or exchange rate movements).



As noted in the earlier version of this paper, perhaps the larger challenge is that as yet, the market for torrefied and steam exploded pellets barely exists. Partially that is due to the persistent failure of the technology developers over a number of years to get the mass and energy balances of the production processes in line with an economic model that works. As shown above, inefficient systems that have a high ratio of wood going in to processed material coming out will fail to deliver $/GJ fuel that is competitive with white pellets. Furthermore, utility buyers are used to white pellets and know that they can be produced consistently and reliably. Finally, there are multiple producers of white pellets with excess capacity so if one plant has an interruption, the demands for fuel can still be fulfilled.

Based on this analysis and on information from several technology providers, it would appear that the mass and energy balance challenge has been met by some major providers who already have a strong presence in the wood pellet sector. The other challenges will take time, patience, and persistence.

Based on our analysis, we would expect that the normal utility grade pellet sometime in the not too distant future will be black.